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Unusual Power Supply Applications

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Power supplies have become very sophisticated in the past few years, performing many unusual tasks. Their applications are limited only by the designer's ingenuity.
Here are some unique uses for power supplies with details on how they do it.

REGULATED POWER SUPPLIES are feedback controlled devices designed to control the electrical parameters of voltage or current. In some power supplies the regulation control loop can be extended to include a variety of physical elements. When this is done, the power supply can be made to regulate position, speed, color, temperature, pressure, chemical activity or the like.

Assuming the necessary transducers and sensors, a servo control mechanism can easily be constructed for any of the above. A bridge-controlled programmable power supply is the heart of the system. It is used to drive a transducer and is, in turn, programmed by the difference—or error—which results from a comparison of the sensor's output with a reference.

* * *

Since bridge-controlled power supplies are readily voltage-programmed, it is usually convenient to convert the sensor's output to a voltage to carry out the comparison.

Voltage Gain

To demonstrate the process of servo regulation, it is necessary to show how a bridge-controlled regulated power supply is capable of dc voltage gain. Consider the simple drawing shown in Fig. 1. In this circuit, the output voltage of the supply E_o is compared to a reference source E_R through the ratio of resistors Rvc (the "voltage control") and R_R, (the "reference resistor").

Assuming that the gain of the amplifier "A" is very large, the equation for this circuit is $E_R/R_R = E_o/R_{vc}$ which can be re-written $E_o = (R_{vc}/R_R)\ E_R$. E_R is commonly the 6.2 v. drop across a precision zener diode built into the power supply. Since E_o can be made almost any value from zero to thousands of volts, (depending upon the design of the power section), the term R_{vc}/R_R can be considered the "gain" of the bridge.

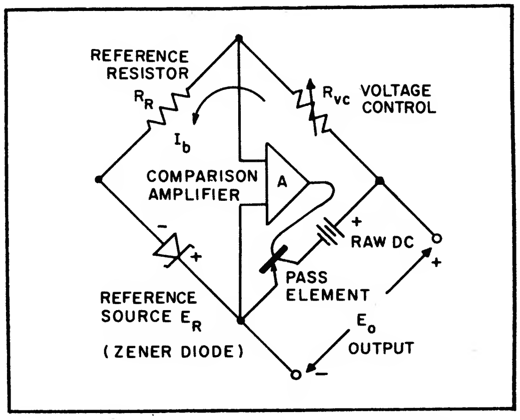


Fig. 1: Simplified power supply comparison bridge schematic. Note: This and all other drawings in this article are drawn for all-transistor power supplies. Hybrid units would require that the polarities be reversed

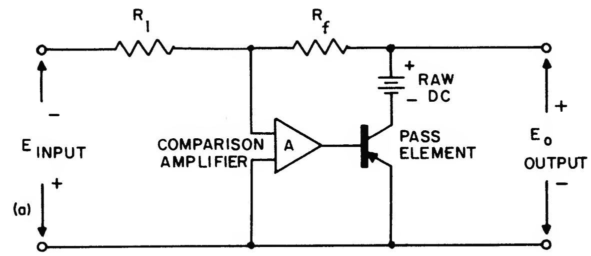
In effect, the reference potential E_R is *amplified* to any desired E_o. Should an external source be substituted for E_R it would also be amplified by the ratio R_{vc}/R_R, and will appear at the output. If external resistors are substituted for R_{vc} and R_R, it is possible to treat the bridge controlled programmable dc power supply as a high power, high gain, dc amplifier. Using operational notation, R_{vc} becomes R_f, the feedback resistor, and R_R becomes the R_1, the input resistor. E_R becomes E input, see Fig. 2A. Fig. 2B is another way of representing this circuit.

The triangle symbol is taken to include all of the remaining power supply elements, the raw power sources, pass elements and comparison amplifier. The operational gain G is the ratio R_f/R_1, and for many power supplies can be adjusted as high as 1000 or more. Thus, the bridge regulated programmable power supply can be used effectively with external operational circuits.

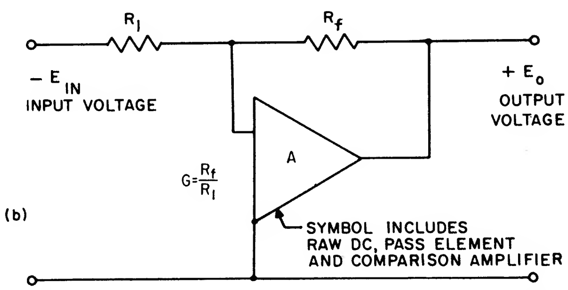
Referring to Fig. 2C and using operational notation, with a reference (or command) input E_c and a feedback sensor voltage E_h the amplifier equation becomes $E_o = (E_c - E_h)(R_f/R_1)$. If the operational gain R_f/R_1 is made sufficiently large, the difference $E_c - E_h$ becomes quite small, and is designated ε, the error.

Describing Control Circuits

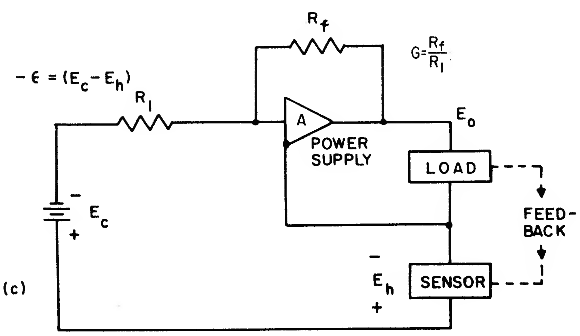
To illustrate this unconventional view of the dc power supply, several relatively simple control circuits will be described. Like all such mechanisms the actual execution in practical form requires attention to the finer points of control system engineering. Questions such as transient behavior, stability and the like will not be treated here. The literature on control systems engineering is fully applicable.



(A): Power supply bridge drawn for external R_f and R_1.



(B): Internal structure of bridge, pass elements, raw dc supplies and comparison amplifier absorbed into single symbol.



(C): Power supply used in a feedback controlled system.

Fig. 2

Speed Control

Motor speed control is a common engineering problem. Often dc motors are used with an adjustable dc power supply to obtain a range of speed control. Unfortunately such an open loop control circuit does not correct for variations in shaft loading or other factors which can tend to upset the speed. To detect such speed changes, an appropriate sensor is required. A permanent magnet tachometer-generator makes a convenient speed sensor. Its dc output is in a form that can readily be used for feedback purposes.

A speed control mechanism is shown in Fig. 3. It consists of an appropriately rated, programmable, dc power supply connected to run a dc motor. This power supply is depicted in operational notation. The dotted "feedback" line represents belt or gear coupling between the load shaft and the tachometer whose output E_h is proportional to the motor shaft speed. A second, small, dc power supply, E_o, is connected series-opposing the tachometer output, so that their difference serves as the input to the main motor-drive supply. This signal $E_c - E_h = \varepsilon$, is amplified through R_f/R_1 to drive the motor. For a large gain, R_f/R_1, output disturbances are greatly diminished by the feedback E_h. If R_f/R_1 is large, ε is small, and E_h will about equal E_o As E_c is varied (by changing the setting of the command power supply E_h follows. Should E_c be increased, the error, ε, increases, which ups the motor drive by $(R_f/R_1)\varepsilon$. This, in turn, speeds the tachometer increasing E_h. The error differential ε is thus diminished, regulating the motor drive and thus its output speed. Any tendency for the shaft speed to change, including the effect of load variations, will be corrected by this control circuit.

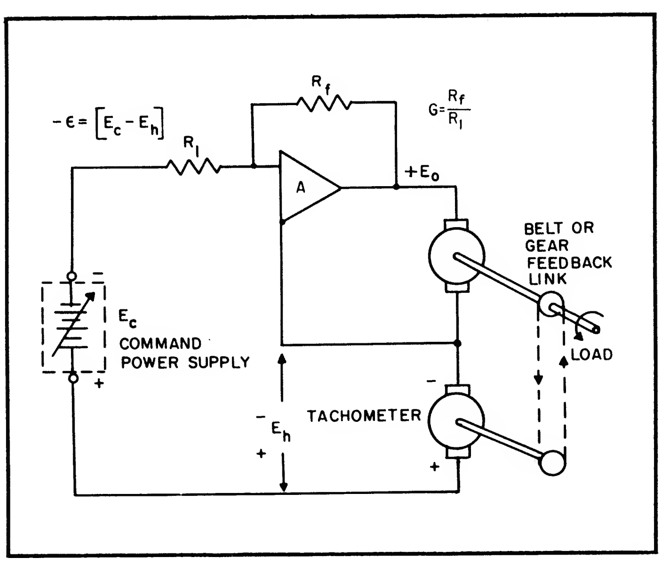


Fig. 3: Speed control using 2 power supplies and tachometer.

Regulating Light Intensity

Another common control problem is the regulation of light intensity. The problem often involves filament, xenon or arc lamps. The uniform illumination of a monochromator is a typical objective. There are several sensors whose output can be used. Photo multiplier tubes and photo voltaic or photo resistive semiconductors are among the most commonly used for feedback control.

Photo voltaic silicon photocells are perhaps the most convenient sensor. Their output, usually requires some voltage amplification before it can be summed differentially with the reference or command potential, E_c. A small dc power supply connected operationally for program-by-voltage serves conveniently to amplify the feeble photocell output. Since this amplifier/power supply is in the feedback loop,

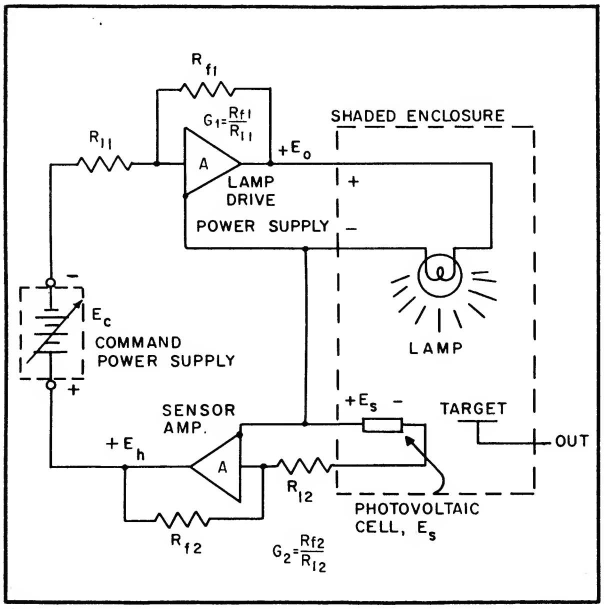


Fig. 4: Illumination control using photo-voltaic sensor and power supply as voltage amplifier G_2, loop gain is G_1G_2.

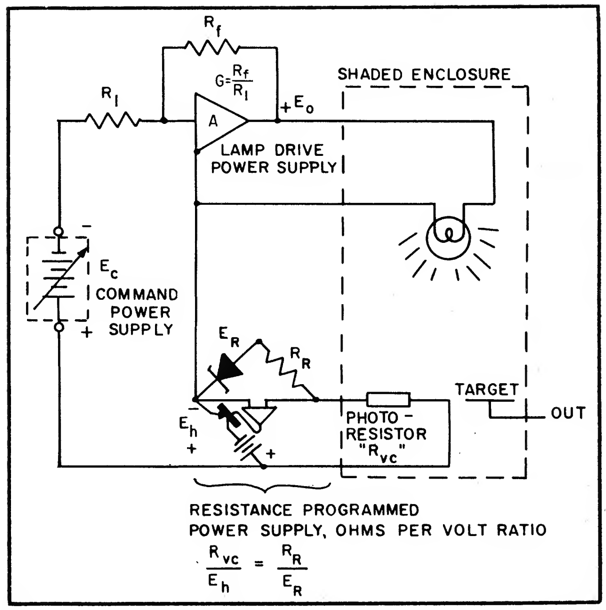


Fig. 5: Illumination control using photo-resistive sensor with programmed power supply as resistance-to-voltage translator.

its gain contributes to the loop gain and thus improves the light intensity regulation. Fig. 4 depicts an illumination servo using a photo voltaic feedback sensor.

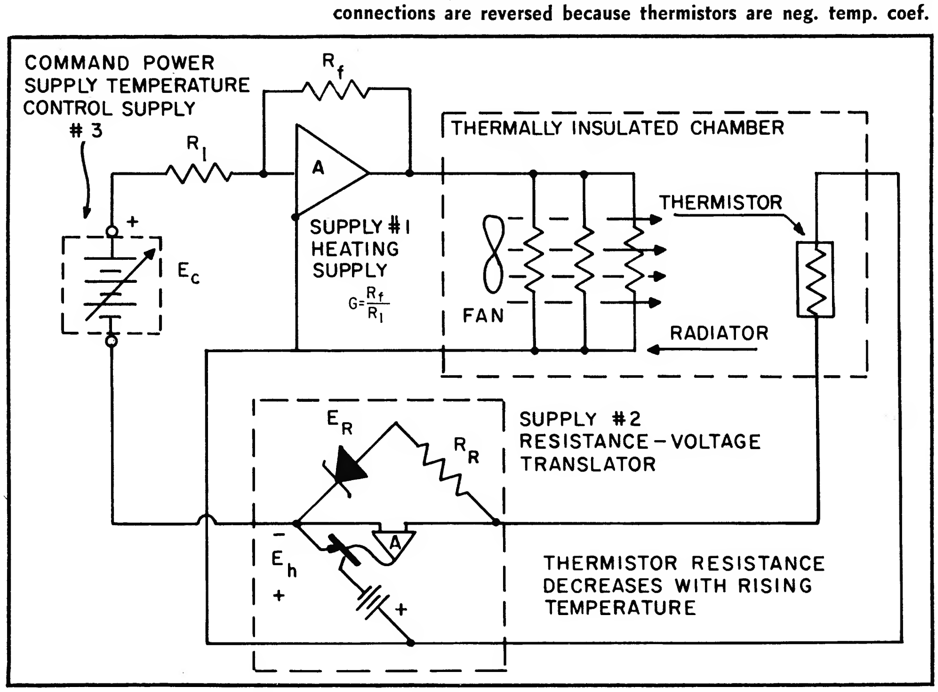
Photo resistive cells might also be used to sense the light intensity. Such a cell generates a variable terminal resistance as a function of the incident illumination. This introduces a translation problem, *resistance to voltage,* for which programmable power supplies are well suited. A power supply is resistance-controlled by connecting the external resistance—or photo resistive cell in place of the voltage control R_{vc}, (or R_f in the operational notation). The built-in reference voltage and resistor E_R and R_R combine to pass a "bridge current" through the programming resistance $I_b=E_R/R_R$. This power supply is said to be controlled at an ohms per volt ratio equal to the reciprocal of the bridge current. Thus for $I_b=1$ ma, the control ratio is 1000Ω/v. For every 1000 ohms change in the photo resistance, the controlled supply yields 1 v. change in output, which voltage can be used as described previously, to form a comparison null with a convenient E_c command reference. E_c is adjustable and also serves as an intensity control. Such a system is sketched in Fig. 5.

Temperature Control

Temperature control is another interesting dc power supply use. Here, the output of an appropriate programmable supply can be used to generate heat directly as the dissipation in suitable resistors. With fans to circulate the air, resistive radiators can be driven by a feedback controlled power supply to produce very precise temperature control. A thermistor, or a group of thermistors, within an insulated thermal chamber, are used to form the temperature feedback sensor. Again as with the photo resistive sensors, a small power supply can be resistance programmed by the thermistor. The feedback voltage E_h would be the sensitivity of the thermistor in ohms per °C divided by the ohm per volt ratio of the translating power supply.

A three-power supply arrangement as shown in Fig. 6 provides excellent temperature control. Supply 1 is the heating supply whose output drives the

Fig. 6: Temperature control using thermistor sensors. Feedback connections are reversed because thermistors are neg. temp. coef.



resistor radiators within the insulated chamber. Supplies 2 and 3 are connected in series opposing to form the voltage differential input to Supply 1. Supply 2 is resistively programmed by thermistors spotted around the interior of the temperature control chamber and produces E_h. Supply 3 provides the command reference E_c which serves as the adjustable temperature control. With a forward gain in Power Supply 1 between 150-200, temperature control to better than 0.1°C can be achieved for very long periods.

Chemical Analysis

Another, related, power supply application involves the field of chemical analysis. Many electro-chemical electrolytic processes are designed to proceed at a rate governed by the voltage appearing at an immersed reference electrode, often calomel. This may be done so as to control which of two possible electrode reactions will occur. Such a process is known as a controlled potential electrolysis and the apparatus designed for the purpose are potentiostats. A potentiostat is easily made using a dc power supply in a simple feedback circuit. As shown in Fig. 7, a programmable power supply is employed to pass current through an electrolyte. The voltage appearing between the "reference" electrode and the working electrode is compared to the output of a command supply, E_c. Their difference serves to control the output of the main electrolysis supply.

An interesting feature of this control arrangement, and one that is essential to the concept of potentiostat, is that the main electrolysis power supply does not draw *any* current from the reference electrode. Any current into or out of this electrode would, of course, upset the accuracy of the experiment. The connection

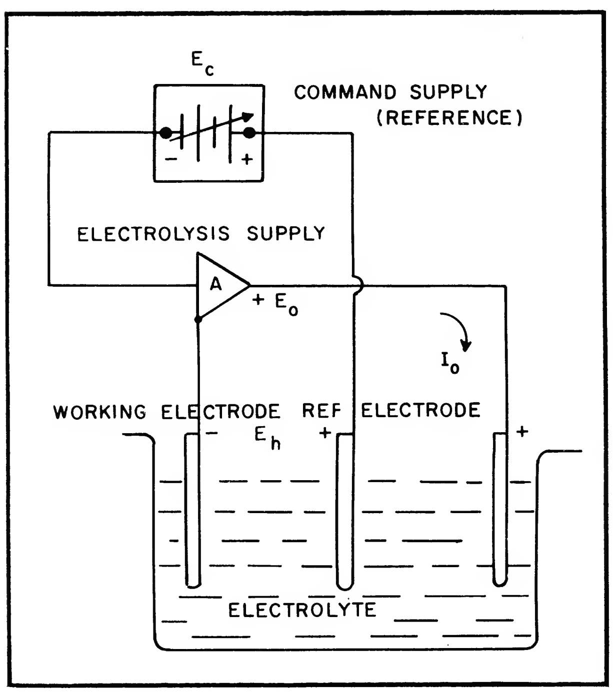


Fig. 7: Potentiostat used for controlled potential electrolysis.

that permits this is called a "half-bridge." How it works can be seen from Fig. 8. Recall, that in the more conventional full bridge or the operational connection, a control bridge current, I_b, flows. As shown, I_b equals E_1/R_1 or E_R/R_R, depending on how the

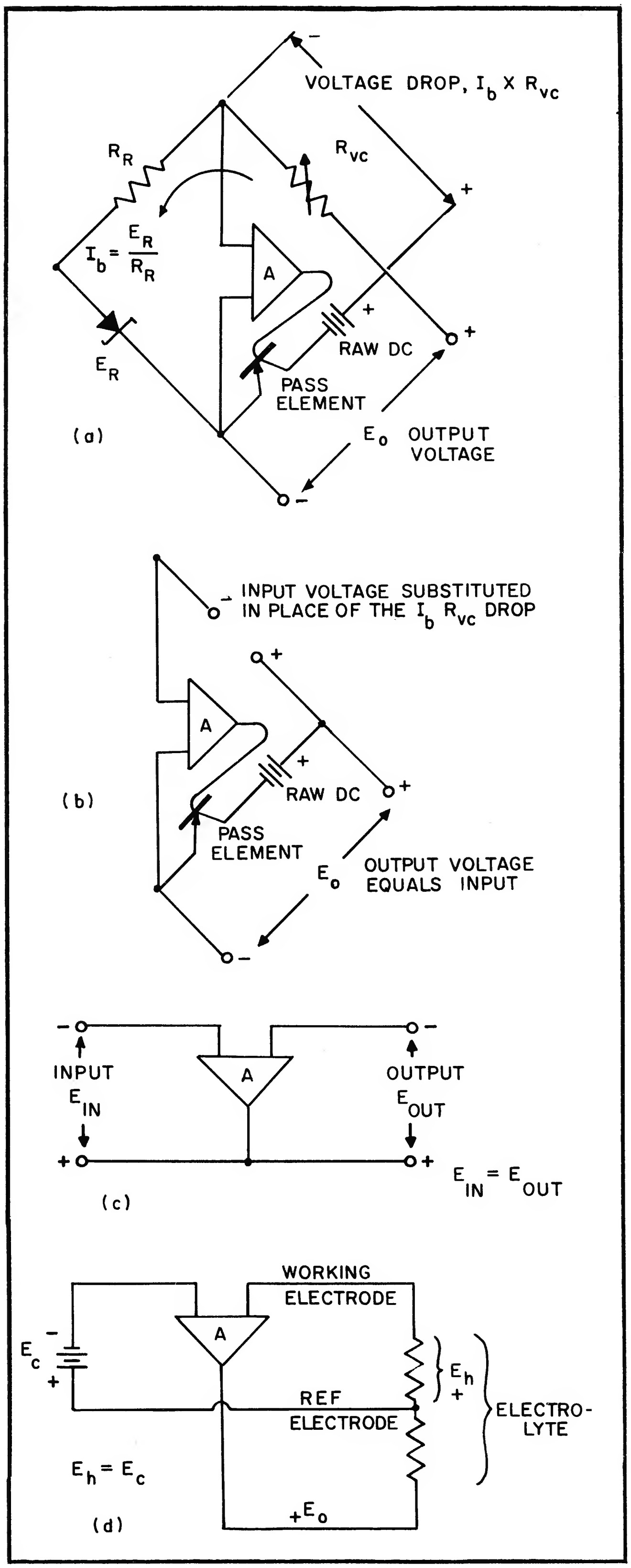


Fig. 8: Using the operational notation of a simple triangle representing the raw dc supply, the pass element, and the comparison amplifier, the "half bridge" becomes a voltage follower, impedance transformer. Fig. 8(d) is a potentiostat.

elements are labeled. I_b also flows through R_{vc} (or R_f as the case may be) and develops a voltage drop across that resistor. The polarity of the voltage across the voltage control or feedback resistor is seen in Fig. 8. Since the amplifier maintains the voltage across its terminals at a virtual zero, or null, the voltage across the output terminals of the power supply must equal the drop across the voltage control. This fact suggests that if a voltage of the correct polarity were applied *in place* of the voltage control/feedback resistor, there would be no need for the bridge current. The output terminals would simply repeat the applied voltage. The output terminals are, of course, a low impedance source and the comparison amplifier ideally draws no current. The result is a form of impedance transformer or voltage follower. An impedance transformer, half bridge, power supply configuration, is a unity gain, 1:1 form of programming where the input impedance is exceedingly high, and the output impedance is very low.

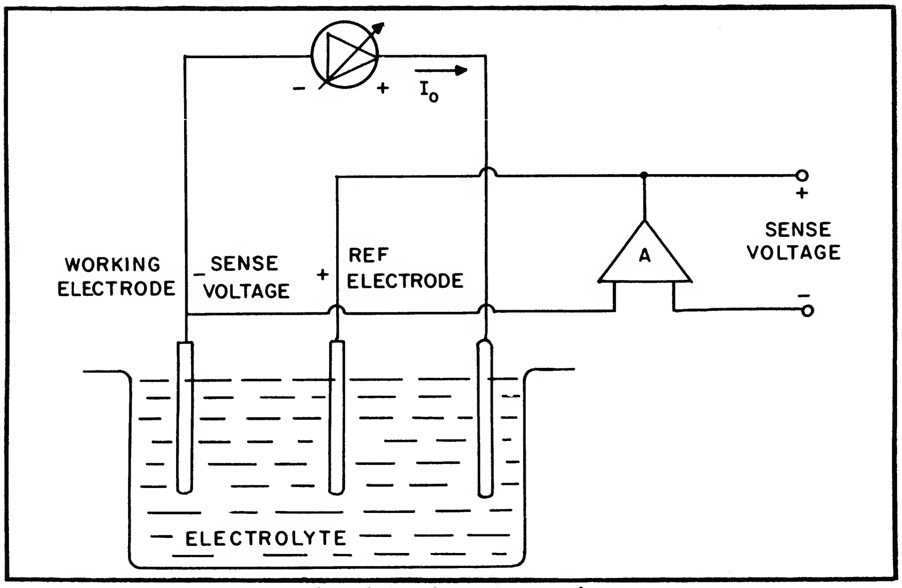


Fig. 9: Constant current electrolysis using power supply to repeat the sense voltage between reference and working electrodes.

In the potentiostat setup, the reference electrode voltage drop, which is a fraction of the total output voltage, is compared directly with the output of the command supply. To maintain the null, the power supply varies the electrolysis current to regulate the reference electrode voltage. Here, the loop gain equals the open loop gain A of the power supply's comparison amplifier, typically 10^4-10^5, see Fig. 8d.

The voltage follower has another useful application to electrochemical electrolysis. In particular, when *constant current* electrolysis is attempted, it is often desirable to monitor the reference electrode potential in order, for example, to be able to detect the depletion of one or more elements in the electrolyte. Here, a separate, small, programmable supply is connected as a voltage follower to repeat the reference electrode voltage. The voltage, when it appears at the output terminals of the repeater is identical to the reference potential except that it is at low impedance, capable of delivering substantial current to monitoring or other control apparatus without drawing any significant current from the reference electrode itself. See Fig. 9

This article has attempted to show some of the ways sophisticated dc power supplies can be used to solve a number of control problems. In every instance, the power supply is used to take advantage of the exceedingly high-gain comparison amplifier built-in for precision regulation. The coupling of a high-gain dc amplifier with the high-power capabilities of the supply's output circuit, provides a unique capability for signal processing and system control.

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